Winter 1999

Inside Tech Transfer

A technology transfer newsletter published for the Department of Energy's National Petroleum Technology Office

Natural Gas & Oil Technology Partnership Bioprocessing Projects Awarded

The Department of Energy's (DOE) National Petroleum Technology Office in Tulsa, Oklahoma, has awarded $1.516 million for research in "downstream processing" as part of its *Natural Gas & Oil Partnership–a successful collaboration of industry and national laboratories*. The Department of Energy, as facilitator for the Partnership Program, provided guidance through an evaluation process which included industry recommendations for specific research needs prior to the submission of proposals. The industry roadmap laid the groundwork for national laboratories responding to the DOE's Call for Proposals in the areas of bioprocessing and air-fine particulates.

The *Natural Gas & Oil Partnership* serves both government and industry by supporting the DOE's Oil & Gas Programs while advancing technologies needed to support the oil and gas industry shift from domestic to global markets. The selection of six new projects in the downstream processing area indicates the successful integration of industry and national laboratory participation in the Partnership Program. DOE will award four projects in bioprocessing and two projects in air-fine particulates. A description of each project and industry/national laboratory teams follows:

Sun Refinery, Tulsa, Oklahoma.

Project Title: *A Predictive Model of Indoor Concentrations of Outdoor PM-2.5 in Homes*

Participants: Aerosol Dynamics, Envair, Western States Petroleum Association, and Lawrence Berkeley National Laboratory

Project Proposal: Investigation of quantitative relationships between particulate-matter concentrations measured as stationary outdoor monitoring sites and the actual breathing-zone exposures of individuals to particulate matter has been identified by the National Research Council Committee on Research Priorities for Airborne Particulate Matter (1998), as one of the ten top research priorities. Determining indoor concentration is particularly crucial because individuals spend, on average, about 90% of the time indoors (70% in homes). The proposed research addresses issues crucial to the quantification of exposure.

Project Title: *Real-Time, Near-Field In-Situ Characterization of Metals in Gas and Aerosol Phases for the Development of a New Source Identification Model*

Participants: University of Minnesota, Oak Ridge National Laboratory, and Oak Ridge Institute for Science Education

Project Proposal: The research team proposes to develop a dynamic fingerprinting technique for resolving PM-2.5 sources. Petroleum sources are of interest in this project. However, the technique requires a new-generation of instrumentation and receptor-oriented modeling technique. Proposed is a two-year research project leveraging ongoing research funded by the Department of Defense for the development of a real-time in situ spectrometer for metal measurement.

Project Title: *Biological Upgrading of Heavy Oils for Viscosity Reduction*

Participants: Chevron Research & Technology Company, Amoco

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Refining Business Group, EPRI Chemicals, Petroleum and Natural Gas Center, and Lawrence Berkeley National Laboratory

Project Proposal: It is hypothesized that bacterial enzymes can be used to produce dihydrodiols of high molecular weight polynuclear aromatic hydrocarbons (PNAs) and that the production of dihydrodiols will result in a decrease in heavy oil viscosity. It is proposed to investigate the production of dihydrodiols and other intermediates using well characterized bacteria that transform PNA with four or more rings without degrading mono-aromatic and aliphatic hydrocarbons.

Project Title: *Enzymatic Upgrading of Heavy Crudes via Partial Oxidation or Conversion of PAH's*

Participants: Texaco E&P Technology, Chevron Research & Technology, and Phillips Petroleum Company, and Oak Ridge National Laboratory

Project Proposal: The objective of this work is to evaluate the ability of enzymes which have been chemically-modified to make them catalytically active and chemically stable in crude oil to upgrade both the quality of heavy crudes and decrease their recalcitrance to further processing. Peroxidases which have been shown to convert polyaromatics to their respective quinones, and other enzymes yet unproven will be investigated for their biorefining potential with particular emphasis upon upgrading of molecular weight, decreasing viscosity, and increased availability of S, N, V and Ni to further refining technologies.

Project Title: *Kinetics of Biochemical Upgrading of Petroleum (BUP)*

Participants: Brookhaven National Laboratory, Shell E&P Technology Company, Chevron Research and Technology Company, and BioCat, Inc.

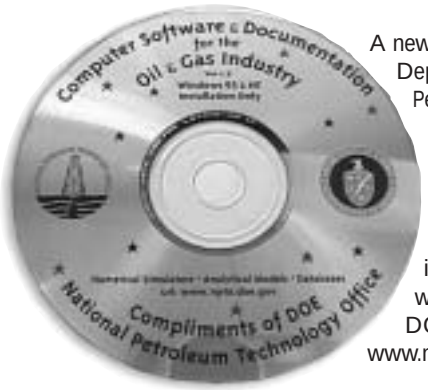
Project Proposal: Brookhaven National Laboratory has developed a process for Biochemical Upgrading of Petroleum that when implemented will significantly contribute to effective environmental protection. The efficiency of the process varies substantially with the biocatalyst used and the chemical properties of heavy crudes. Economic analysis of the worst case scenario, e.g., batch reactor, 36-hr treatment and a 30% removal of sulfur shows the process to be cost efficient under defined conditions.

Project Title: *Bioprocessing of High Sulfur Crudes via Application of Critical Fluid Biocatalysis*

Participants: Idaho National Engineering and Environmental Laboratory, Florida State University, and UOP.

Project Proposal: Idaho National Engineering and Environmental Laboratory (INEEL) will explore bioprocessing of high sulfur crude oil at critical fluid conditions. Utilization of high sulfur fuel products results in production of gaseous sulfoxide compounds that are believed to be partially responsible for ''acid rain.'' Biological removal of sulfur from crude oil is an attractive process to mitigate this environmental problem. However, there are significant practical limitations of bioprocessing including low solubility in water and mass transfer limitations across oil-water interfaces, relatively slow reaction rate kinetics, catalyst recycle, requisite separation technologies to recover desired products, and maintenance of biological integrity. Critical fluids may provide several advantages for the bioprocessing of high sulfur crude oil, including

Exploration & Production Software Available on CD-ROM from the National Petroleum Technology Office



A new CD-ROM available from the US Department of Energy's (DOE) National Petroleum Technology Office contains more than 20 programs, database applications, and model documentation files for the oil and gas industry. *BOAST '98*, the newest version of DOE's popular BOAST software, debuts on the CD-ROM. In addition, it features an installation program that describes the software and assists users in installation. Other DOE software is available at www.npto.doe.gov/software/software.html

To obtain a complementary copy of the CD-ROM, contact Herb Tiedemann, NPTO technology transfer officer, 918-699-2017, htiedema@npto.doe.gov

high solubility of organic compounds, enhanced mass transfer rates due to elimination of liquid/liquid interfaces, enhanced reaction kinetics and approach to equilibrium, an energy efficient separation of end products. This research program will concentrate on critical fluid processing and enzyme biocatalysis for removal of heteroatomic species form select oil fractions.

Nine multi-program national labs participate in the Partnership Program in the following technology areas: oil & gas recovery technology, diagnostic & imaging technology, drilling, completion & stimulation technology, advanced computational technology initiative, environmental technology, and downstream processing technology.

Among those participants are **Argonne National Laboratory**, **Brookhaven National Laboratory**, **Idaho National Environmental and Engineering Laboratory**, **Los Alamos National Laboratory**, **Lawrence Berkeley National Laboratory**, **Lawrence Livermore National Laboratory**, **Oak Ridge National Laboratory**, **Pacific Northwest National Laboratory**, and **Sandia National Laboratory**.

For additional information about the Natural Gas & Oil Technology Partnership contact Alex Crawley at the National Petroleum Technology Office, (918) 699-2055; for information about Downstream Processing Technology contact Dexter Sutterfield at the National Petroleum Technology Office, (918) 699-2039; or visit the Natural Gas & Oil Technology Partnership Home Page http://www.sandia.gov/ngotp.

National Petroleum Technology Office Offers Technology Development Assistance To Independents

A new Department of Energy (DOE) program administered by the National Petroleum Technology Office offers small independent oil operators solutions for oil production problems. Proposals for the program, "Technology Development with Independents," will be accepted four times during the year-long period. DOE awards will be similar to past levels of effort. Cost sharing of the required minimum 50% of total proposed project costs may consist of in-kind contributions. The program is intended for small operators with less than 50 employees and no affiliation with a major oil or gas producer (domestic or foreign).

The proposals should incorporate new and innovative concepts, ideas, and approaches to oil production problems and should lead to increased production, reduced operating costs, reduced environmental concerns, or combinations thereof. Types of technology areas the DOE will consider for this program include reservoir characterization, well drilling, completion or stimulation, environmental compliance, artificial lift, well remediation, secondary or tertiary oil recovery and production management.

Independents at NPTO-sponsored workshop.

Contractors must successfully demonstrate and implement an aggressive technology transfer plan targeted at small independent petroleum operators. The period of performance for these awards is 12 months, but proposals with a shorter period of performance will be considered. Award decisions will be based on technical merit, subject to costs and availability of funds. DOE will accept proposals Mar. 31, May 31, Aug. 31, and Nov. 30, 1999.

Questions should be directed to Jim Barnes at NPTO, 918-699-2076 (Phone) or 918-699-2005 (Fax), or visit the NPTO web site: http://www.npto.doe.gov.

For publications contact Herbert A. Tiedemann, Project Manager for Technology Transfer, 918-699-2017 or by email at htiedema@npto.doe.gov.

Fundamental Geoscience for Reservoir Characterization Improves Recovery Efficiency

In 1996, the Department of Energy's (DOE) National Petroleum Technology Office (NPTO) awarded seven contracts for improving knowledge of petroleum reservoirs with complex fracture systems in which oil production is often hindered by the natural fractures that run through the reservoir rock. DOE predicts that reserves in fractured reservoirs would increase by 32 million barrels within 11 years as a result of the research.

DOE provided $4.8 million for the seven contracts awarded to Alabama Geological Survey, Golder Associates, Science Applications International Corporation, Southwest Research Institute, TerraTek, the Bureau of Economic Geology at the University of Texas at Austin, and the University of Utah. The research organizations matched the DOE funding increasing the value of the projects to $9.9 million.

The DOE Program proposes to quantify reservoir architecture, dynamics of fluid-rock and fluid-fluid interactions related to lithologic characterization, and impacts on producibility. The two- to three-year projects underway are studying the relationship of geologic stress and local fracture patterns to regional tectonic systems and developing techniques to use this information to predict petroleum recovery.

Research methods require the acquisition and integration of characterization data from a wide variety of scales and the quantitative development of interrelationships based on scale definition as it relates to oil reservoirs. Interdisciplinary efforts focus on increasing well-to-well predictability for improving recovery efficiency from geologic formations containing known oil reservoirs, and incorporating data from outcrop (mesoscopic) to core and pore (microscopic) scales.

Alabama Geological Survey

Area Balance and Strain in an Extensional Fault System: Strategies for Improved Oil Recovery in Fractured Chalk, Gilbertown Field, SW Alabama

Location: Alabama, Selma Chalk and Eutaw Formation, Gilbertown Field, SW Alabama

Project Description: The Geological Survey of Alabama will compile data on the fractures in the Selma Chalk and Eutaw Formation to help identify the best improved recovery methods for Gilbertown Field. Analyses of core samples and well logs will provide information on rock composition, oil and gas saturation, and other critical parameters. Structural and stratigraphic maps and cross sections derived from surface and subsurface data will document the strain in the Gilbertown fault system and its effect on fracturing. Computer modeling of these geologic data and well performance characteristics will provide understanding of the influence of regional tectonics on local oil production and allow producers to identify where improved operations will be most beneficial. Results from the project will be disseminated to regional operators by the survey's Petroleum Technology Transfer Center in Tuscaloosa.

Results: Comparison of completed zones with structural data indicates that a significant amount of untapped oil may still be in Gilbertown Field. In the structurally highest part of the field, the glauconitic sandstone units in the upper Eutaw formation are behind casing. Recompletion of existing wells has potential to add up to 60 ft of productive section in this area. Examination of Selma completion patterns indicates that many of the oldest wells were completed as much as 250 ft below the reservoir seal. Infilling, deviation of existing boreholes, and horizontal drilling are methods that have potential to revitalize Selma production.

Contact: J.C. Pashin, (205) 349-2852; (205) 349-2861,

Bureau of Economic Geology (BEG), University of Texas at Austin

Using Microstructure Observation to Quantify Fracture Properties and Improve Reservoir Simulation

Location: Texas, Spraberry Formation and Blanco Mesaverde Gas Field, San Juan Basin West Texas

Project Description: BEG is working with an industry user group to develop fracture data from core samples in BEG's Core Research Center. Research teams will conduct comprehensive analyses and imaging on outcrops that are analogous to reservoir strata to determine the relationship between microscale history of the units. Using Core Research Center samples, two reservoir formations are being analyzed in a similar fashion, models developed that will show processes that open or close flow paths, and the results compared with the outcrop analog information. Fracture-mapping methods resulting from these two tasks will be used to develop improved simulation techniques for modeling the particular reservoirs under study and in adapting outcrop and core data for use in the models.

Results: BEG researchers have made several major discoveries regarding the scaling of natural fractures in petroleum reservoir rocks:

- New techniques were developed for measuring the mechanical apertures of fractures in cores and outcrops.
- Data sets were collected to confirm that microfractures and macrofractures follow the same fractal distributions. This provides a solid basis for using microfracture observation to predict the spatial frequencies of macrofracture apertures, a key to reservoir simulation.
- BEG researchers have repeatedly found that fracture attributes follow power-law fractal scaling.
- The feasibility of measuring statistically significant numbers of microfracture lengths and mechanical apertures from small borehole samples has been demonstrated through numerous examples.

Contact: S.E. Laubach, (512) 471-1534; (512) 471-0140

Golder Associates, Inc.

Fractured Reservoir Discrete Fracture Network Technologies

Location: Texas, Pecos and Crockett Counties, Permian Basin, Yates Field Tracts 17 & 49

Project Description: Golder Associates, working with Marathon Oil Company and the Massachusetts Institute of Technology (MIT), will develop a reservoir fracture model that can be used to implement thermally-assisted gravity segregation (TAGS), a cost-effective recovery process that combines the natural tendencies of fracture flow segregation, gravity segregation, and composition/thermal phase behavior in fractured reservoirs. Combining Marathon's data on fracture stress field and fluid-flow relationships and MIT's fracture-plane hydraulic data and fracture network modeling, Golder Associates will develop and apply a reservoir model to the West Texas Yates field to demonstrate its ability to predict the TAGS process and assist in developing reservoir-specific oil recovery processes.

Results: Hierarchical fracture models have been developed. A three-dimensional model of rock fracture systems was presented. The model is geometric-mechanical: it represents the 3-D fracture systems geometry based on its relationship with the underlying geologic mechanisms, without modeling the mechanics itself. The 3-D model was applied to model the fracture system in the sedimentary reservoir rocks of the Yates oil field in West Texas. The results from this study indicates that the 3-D hierarchical geometric-mechanical model has the capability of representing important fracture system characteristics such as fracture orientations related to general stress directions and local geologic structures and fracture intensity as a function of different material properties.

Contact: W.S. Dershowitz, (206) 885-7648; (206) 882-5498.

Science Application International Corp. (SAIC)

Naturally Fractured Reservoirs: Optimized E&P Strategies Using a Reaction-Transport-Mechanical Simulator in an Integrated Approach

Location: Texas, Midland County, Andector-Goldsmith Fields, Permian Basin, West Texas

Project Description: SAIC will

work with Indiana University and Phillips Petroleum Company to integrate advanced geoscience techniques with reservoir engineering concepts to optimize exploration and production strategies for naturally fractured oil reservoirs. The location, reservoir characteristics, and spatial extent of such reservoirs will be predicted by integrating seismic and other geological and engineering data with a geochemical-geomechanical simulator. Through this combination of physical and chemical laws with more traditional exploration and production (E&P) data, SAIC will develop a reservoir model that can yield more efficient exploration and production strategies. The methodology and results will be demonstrated using Gandu field in the Permian Basin.

Results: A reaction-transport-mechanical (RTM) model developed at Indiana University Laboratory for Computational Geodynamics has been modified to model specific problems inherent in simulating the Permian Basin evolution. The structural geology and tectonics of the Permian Basin were determined using an integrated approach incorporating satellite imagery, aeromagnetics, gravity, seismic data regional subsurface mapping, and published literature.

Project researchers have developed a number of unique and very promising new technologies for basin/reservoir modeling-based prediction of fracturing in petroleum reservoirs. These technologies are being tested in the Permian Basin. Up-to-date results will be posted on the Indiana University website when available.

Contact: Tom Devlin, (703) 556-7158.

Southwest Research Institute (SwRI)

Characterization of Fractured Reservoirs Using Static and Dynamic Data: From Sonic and 3D-Seismic to Permeability Distribution

Location: Utah, Summit County, Lodgepole Field; California, Kern County, Buena Vista Field.

Project Description: SwRI will evaluate acoustic logging and 3D-seismic measurement techniques, as well as fluid flow and transport methods, to map reservoir fluid flow and other parameters to increase understanding of reservoir fracture systems and associated fluid dynamics. The principal application of these measurement techniques and methods will be to identify and investigate the propagation characteristics of acoustic and seismic waves in the Twin Creek reservoir owned by Union Pacific Resources and to characterize the fracture permeability distribution using production data.

Results: An analytical solution for plane-harmonic seismic waves propagating in a poroelastic anisotropic media was developed. Also, software was developed to calculate fluid pressure, the vector wavefield, and the displacement of the fluid relative to the solid. This software provided the relationship between permeability anisotropy and the dispersion and attenuation seismic signatures. The geological cross-sections with migrated seismic data, the velocity inversion, and FMS data information delineated the major geological units of interest in the reservoir. The model was used to calculate synthetic seismic signatures for planning cross-well seismic surveys between wells at Lodgepole Field. A methodology was developed for building a high-resolution velocity model within available well control. This is a self-consistent velocity/attenuation model that can be used to predict permeability distribution from crosswell and/or surface seismic data. A 3-D streamline simulator for modeling multiphase flow and transport in heterogeneous permeable media was developed and tested. Results from the streamline model were validated against commercial numerical simulators. A new procedure called “structure preserving and multiphase production history into stochastic reservoir models.

Contact: J.O. Parra, (210) 522-3284; (210) 647-4325.

Terra Tek, Inc.

Advanced Fracture Modeling in the Uinta Basin (Utah) for Optimizing Primary and Secondary Recovery

Location: Utah, Uinta County, Duchesne County

Project Description:

Terra Tek will implement advanced geological, geotechnical, and reservoir engineering methods to model the complex fracture networks exhibited at the surface and in comparatively shallow settings along the Duchesne Fault Zone in the Uinta Basin. Activities in the project will include determining how fluids flow through matrix and fractured samples from Balcron and Duchesne Fields, delineating the fracture systems and stress conditions and their effect on fluid flow as reservoir pressure changes, and predicting and verifying primary recovery in naturally fractured reservoirs using reservoir modeling and simulation.

Results: A computer code was developed to model the permeability of deformable fracture networks in two dimensions. This code has the ability to (1) model and include the stress tensor in either principal or non-principal reference frame, and (2) account for the effects of both shear and normal stresses on fracture aperture. A computer algorithm was developed for modeling permeability in fractured rocks and tested using fracture patterns from several oil reservoirs.

- Basin-scale numerical modeling using discontinuous deformation methods (DDM) has been implemented and is defining "sweet spots" in the field for preferred drilling.

- Numerical methods for modeling stress-sensitive permeability associated with 2-D and 3-D fracture networks. A 3-D fractured reservoir visualization model has been developed.

Contact: John McLennan, (801) 584-2474.

University of Utah

Characterization and Simulation of an Exhumed Fractured Petroleum Reservoir

Location: Nevada, White Pine County, Yankee gold mine in the southern Alligator Ridge mining district

Project Description: University of Utah will use detailed field data from an analog fault- and fracture-controlled oil reservoir to develop predictive models of fault and fracture distributions, geometries, and fluid flow characteristics. (The analog reservoir is a geologically exhumed mining district that exhibits a suite of fault and fracture systems found in many hydrocarbon reservoirs.) The resultant models will be incorporated into numerical reservoir simulators to address production from fractured reservoirs and perform tests of different production strategies.

Results:

An integrated understanding of the geologic/tectonic history of the analog fractured reservoir is largely complete. The analog reservoir exhibits characteristic fracturing, veining, and dissolution features that are likely to be found in producing reservoirs located in similar geologic settings. Preliminary models of reservoir-scale faults and interwell/wellbore scale fracture networks indicate that the methodologies needed to create a final set of fracture models is almost in place. A multiphase, discrete-fracture finite element model has been developed. The multiphase-model developed in this study offers a true alternative to the conventional fractured reservoir simulation approach by explicitly accounting for realistic networks of discrete fractures.

Contact: D.L. Nielsen, (801) 585-6655; (801) 585-3540

In conclusion, these projects have made measurable advances in technology approaches for understanding and quantifying fractures and fluid-flow through fractured reservoirs. Several workshops on the subject projects are planned, either by the R&D groups or in cooperation with specific regions of the Petroleum Technology Transfer Council.

For more information about DOE's Geoscience Program contact Robert Lemmon, Technology Manager at the National Petroleum Technology Office, 918/699-2035 or e-mail blemmon@npto.doe.gov.

Coming Attractions

March

Society of Petroleum Engineers Mid-Continent Operations Symposium, Myriad Convention Center, Oklahoma City, Oklahoma, March 28-31, 1999. Visit NPTO booth #5, contact Helen Bresson at (918) 699-2014.

April

AAPG Annual Meeting, San Antonio, Texas, April 11-14,1999. Visit NPTO booth #594, contact Helen Bresson at (918) 699-2014.

May

Offshore Technology Conference, Astrodome, Houston, Texas, May 3-6, 1999. Visit NPTO booth #4201, contact Helen Bresson at (918) 699-2014.

Marginal Well Commission Trade Fair, Ponca City, Oklahoma, May 13, 1999, contact Helen Bresson at (918) 699-2014.

Opportunities for Tribal Land Petroleum Resource Development in the DOE Native American Initiative Program, workshop at the BIA 9th Annual National Indian Energy and Minerals Conference, Golden, Colorado, May 25-27, 1999, contact Virginia Weyland at (918)-699-2041.

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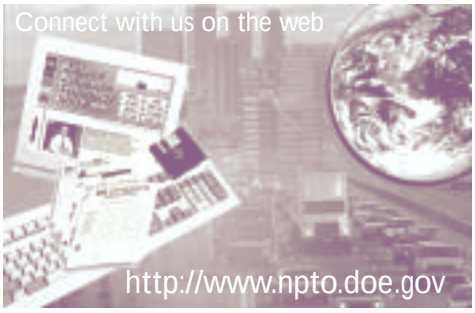

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For more information on two new DOE programs, the ***Class Revisit*** and ***Technology Development With Independents***, visit the Fossil Energy Business Center at http://www.fetc.doe.gov.

SNAPSHOT OF SUCCESS
1999 OKLAHOMA SCIENCE BOWL

1999 Oklahoma Western Regional Science Bowl winners: Yukon High School.

1999 Oklahoma Eastern Regional Science Bowl winners: Jenks High School.

Getting to the finals in the Oklahoma Science Bowl is no easy task considering the competition. Eastern Regional Science Bowl Winners Jenks High School wrapped up the competition by eliminating 23 teams before defeating Owasso High School to finish first. Then, Yukon High School finished first in the Western Regional Science Bowl Competition by defeating Edmond's Santa Fe High School, one of the twenty-five teams entered in the second competition. The two Oklahoma teams will be among an elite group of regional winners from around the Nation when they compete at the National Science Bowl in Washington, D.C., April 30-May 2.

In Oklahoma alone, more than 50 high schools participated in the regional science and math competitions. The Department of Energy's National Petroleum Technology Office sponsors the Oklahoma Science Bowl to recognize the commitment of Oklahoma students and teachers who excel at and support science and math education. Over 100 Tulsa-area high school students competed in the Oklahoma Eastern Regional Science Bowl held at The University of Tulsa on Saturday, January 23. And in the Oklahoma Western Regional Science Bowl held at the University of Oklahoma, February 13, 125 students participated.

Nationwide, during January and February, 9,000 high school students from 1,800 participating high schools compete in approximately 50 regional competitions. The competitions are coordinated by the Department of Energy and other Federal agency personnel and contractors. And, more than 5,000 volunteers from local businesses, colleges, and universities and middle and high schools serve as moderators, timekeepers, and scorekeepers. Regional winners are then invited by the Department of Energy to compete at the National Science Bowl.

The National Science Bowl was initiated in 1991 by the Department of Energy to give national recognition and to provide a forum for those outstanding students and their teachers who demonstrate excellence in math and science during the competitions. The Department of Energy further acknowledges the commitment of participants and their talent and hard work as the key to our nation's future. For more information about the National Science Bowl, visit the DOE website at http://www.doe.gov under Science Education.

For information about the Oklahoma Science Bowl, contact Herbert A. Tiedemann at the National Petroleum Technology Office, 918/699-2017, email htiedema@npto.doe.gov or visit the NPTO Education Web Site at http://www.npto.doe.gov/educate.html.